



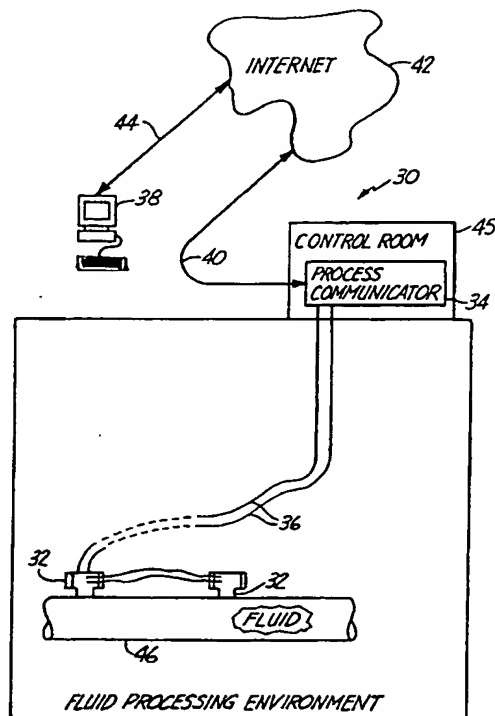
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>G05B 19/418, 19/042</b>		<b>A1</b>	(11) International Publication Number: <b>WO 99/19782</b>
			(43) International Publication Date: 22 April 1999 (22.04.99)
(21) International Application Number: PCT/US98/21339 (22) International Filing Date: 12 October 1998 (12.10.98) (30) Priority Data: 60/061,754          13 October 1997 (13.10.97)          US (71) Applicant: ROSEMOUNT INC. [US/US]; 12001 Technology Drive, Eden Prairie, MN 55344 (US). (72) Inventors: ERYUREK, Evren; 4952 York Avenue South, Minneapolis, MN 55410 (US). WARRIOR, Jogesh; 805 Runningwood Circle, Mountain View, CA 94040 (US). (74) Agents: CHAMPLIN, Judson, K. et al.; Westman, Champlin & Kelly, P.A., International Centre, Suite 1600, 900 Second Avenue South, Minneapolis, MN 55402-3319 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published With international search report.	

(54) Title: COMMUNICATION TECHNIQUE FOR FIELD DEVICES IN INDUSTRIAL PROCESSES

## (57) Abstract

A process device (32) is adapted to couple to a process control loop (36) and communicate on the process control loop (36). Communication on the process control loop (36) is effected in accordance with an internet protocol. A process communication device (34) is also provided which couples to the process control loop (36), and an internet (42). The process communication device (34) provides process control information received from the process control loop (36), to the internet (42). Conversely, the process communication device (34) also provides information received from the internet (42) to the process control loop (36).



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

## COMMUNICATION TECHNIQUE FOR FIELD DEVICES IN INDUSTRIAL PROCESSES

### BACKGROUND OF THE INVENTION

5 The invention relates to the fluid process control industry. More specifically, the invention relates to field devices used in the process control industry and the manner in which those field devices communicate.

10 Field devices such as transmitters, are used in the process control industry to remotely sense a process variable. Field devices such as actuators, are used by the process control industry to remotely control physical parameters of a process, such as flow rate, temperature, etc. The process variable may be  
15 transmitted to a control room from a field device such as a transmitter for providing information about the process to a controller. A controller may then transmit control information to a field device such as an actuator to modify a parameter of the process. For  
20 example, information related to pressure of a process fluid may be transmitted to a control room and used to control a process such as oil refining.

Process variable transmitters are used to monitor process variables associated with fluids such as  
25 slurries, liquids, vapors and gasses in chemical, pulp, petroleum, gas, pharmaceutical, food and other fluid processing plants. Process variables include pressure, temperature, flow, level, pH, conductivity, turbidity, density, concentration, chemical composition and other  
30 fluid properties. Process actuators include control valves, pumps, heaters, agitators, coolers, solenoids, vents and other fluid controlling devices.

-2-

One typical prior art technique for transmitting information involves controlling the amount of current flowing through a process control loop. Current is supplied from a current source in the control room and the transmitter controls the current from its location in the field. For example, a 4mA signal can be used to indicate a zero reading and a 20mA signal can be used to indicate a full scale reading.

More recently, transmitters have employed digital circuitry which communicates with a controller using a digital signal which is superimposed onto the analog current signal flowing through the process control loop. One example of such a technique is the Hart Foundation HART® communication protocol. The HART® protocol and other such protocols typically include a set of commands or instructions which can be sent to the field device to elicit a desired response, such as device control or interrogation.

Fieldbus, another communication protocol, is proposed by the Foundation™ Fieldbus and is directed to defining a communication layer or protocol for transmitting information on a process control loop. The Fieldbus protocol specification is ISA-S50.01-1992, promulgated by the Instrument Society of America in 1992. Fieldbus is a process industry communications protocol described in Fieldbus Technical Overview Understanding Foundation™ fieldbus technology (1998) available from Rosemount Inc. in Eden Prairie, Minnesota. Some protocols comparable to Fieldbus include Controller Area Network (CAN), Lonworks, and Profibus. In the Fieldbus protocol, the current flowing through the process control loop is not used to transmit an analog signal. Instead, all information is digitally transmitted. Further, the Fieldbus protocol allows

-3-

field devices to be configured in a multi-drop configuration in which more than one field device is connected on the same process control loop.

5 The HART® protocol and more recently the  
Fieldbus protocol have been relatively effective at  
communicating process information over process control  
loops. Current process control systems generally  
include many field devices and actuators coupled to a  
given process control loop which is in turn coupled to  
10 a controller. If it is desirable to provide process  
control information on an enterprise-wide level, such as  
throughout an entire company, the controller itself is  
coupled to an enterprise-wide data network, such as an  
Ethernet data network, and the controller provides  
15 information about the process to the enterprise.

#### SUMMARY OF THE INVENTION

The invention includes a process device which  
is adapted to couple to a process control loop and  
communicate on the process control loop. Communication  
20 on the process control loop is effected in accordance  
with an internet protocol.

A process communication device is also  
provided which is adapted to couple to a process control  
loop, and the Internet. The process communication  
25 device provides process control information received  
from the process control loop, to the internet.  
Conversely, the process communication device also  
provides information received from the internet to the  
process control loop.

#### 30 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a system block diagram of a process  
control system in accordance with an embodiment of the  
invention.

-4-

FIG. 2 is a system block diagram of a process device in accordance with an embodiment of the invention.

5 FIG. 3 is a cross-section view of a process device in accordance with an embodiment of the invention.

FIG. 4 is a cross-section view of a process device in accordance with an embodiment of the invention.

10 FIG. 5 is a cross-section view of a process device in accordance with an embodiment of the invention.

15 FIG. 6 is a flow chart of a sequence of process steps to implement an embodiment of the invention with software.

FIG. 7 is diagrammatic view of a data structure in accordance with an embodiment of the invention.

20 FIG. 8 is a system block diagram of a process communication device in accordance with an embodiment of the invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

25 FIG. 1 is a system block diagram of process control system 30 showing the environment of one embodiment of the invention. Process control system 30 includes process devices 32 coupled to a process communication device 34 through process control loop 36. Process communication device 34 is coupled to computer 38 (also referred to as client node 38) through  
30 communication link 40, internet 42, and node link 44. Process communication device 34 may be disposed in a control room such as control room 45 which may provide an intrinsic safety barrier in accordance with APPROVAL STANDARD INTRINSICALLY SAFE APPARATUS AND ASSOCIATED

-5-

APPARATUS FOR USE IN CLASS I, II AND III, DIVISION 1  
HAZARDOUS (CLASSIFIED) LOCATIONS, CLASS NUMBER 3610,  
promulgated by Factory Mutual Research October, 1988.

Fluid processing environments are a special  
5 application for process devices such as transmitters and  
actuators because vapors can be present in these  
environments which can be ignited by an electrical spark  
having enough energy to ignite the vapors. Accordingly,  
communication busses in fluid processing environments  
10 typically are energy limited. Multiple redundant  
circuits are used to ensure that energy levels on the  
busses are below a safe energy level so that they cannot  
produce ignition of flammable vapors, even under fault  
conditions. Transmitters and actuators are energy  
15 limited. Busses which pass through the safe area of the  
fluid processing environment to outside equipment such  
as control room equipment typically pass through energy  
limiting barriers so that a fault outside the fluid  
processing environment cannot cause a spark inside the  
20 frequently explosive fluid processing environment.  
Busses which have the potential for higher level signals  
which could spark under fault conditions are often not  
permitted to pass through or connect to equipment in a  
fluid processing environment. A typical internet  
25 connection, such as communication link 40 or node link  
44 is thus normally excluded from the fluid processing  
environment because its physical layer lacks electrical  
energy limiting safety features. In some cases,  
explosion-proof housings and conduits are used to  
30 contain high energy or power circuits to provide energy  
limiting.

Process devices 32 are coupled to a process  
fluid container such as pipe 46 as shown in FIG. 1. A  
process device is any device which either relates a

-6-

signal to a process parameter, or responsively effects a change in a process parameter. As such, process devices 32 may be transmitters sensing a process variable such as pressure, temperature or level in a process container such as pipe 46. Further, process devices 32 may also be actuators controlling a process variable such as fluid flow or temperature, or a device which monitors operation of a process or sends information related to the process on a process control loop.

Process control loop 36 couples process devices 32 to process communication device 34 and may supply energization current to process devices 32. A process control loop may be any process control configuration where two or more conductors provide communication for devices on the loop. As such, process control loop 36 may be a process control loop in accordance with such process communication protocols as the low-speed Fieldbus protocol (H1), the high-speed Fieldbus protocol (H2), the HART® protocol, or other suitable protocols which provide transmission of digital information on a process control loop.

Process communication device 34 is coupled to communication link 40. Communication link 40 may be any appropriate data connection, such as an Ethernet data connection (as defined by IEEE 802.3, promulgated by the Institute of Electrical and Electronic Engineers), or a point-to-point serial modem connection. As will be described later in greater detail, process communication device 34 is adapted to communicate on process control loop 36, and on communication link 40. As such, when process communication device 34 receives data from communication link 40, process communication device 34 places such data on process control loop 36.



-7-

Conversely, when process communication device 34 receives process control data from two-wire process control loop 36, process communication device 34 places such data on communication link 40.

5 As can be seen in FIG. 1, communication link 40 is coupled to internet 42. Internet 42 is any combination of two or more data networks coupled together. For example, internet 42 may be the public Internet, or internet 42 may also be a private,  
10 enterprise-wide intranet. Internet 42 is coupled to client node 38 through node link 44. As with communication link 40, node link 44 may be any appropriate link, for example, an Ethernet connection, or a point-to-point serial modem connection.

15 As will be described in greater detail later in the specification, devices 32, 34, 38 are adapted for internet communication. An example of such internet adaptation includes the use of an internet protocol suite known as Transmission Control Protocol/Internet  
20 Protocol (also referred to as TCP/IP). Transmission Control Protocol/Internet Protocol is a known internet protocol suite which is generally used for data communication over the public Internet. A Brief Tutorial of the TCP/IP Internet Protocol Suite may be  
25 obtained from the Network Working Group as RFC 1180, published January 1991.

When devices 32, 34, and 38 are adapted for internet communication using Transmission Control Protocol/Internet Protocol, client node 38 may access  
30 process devices 32 by sending a process information request to an internet address of one of process devices 32. Through known methods, the information request is eventually passed through the internet to process communication device 34. Process communication device

-8-

34 transforms the request to a form appropriate for transmission upon process control loop 36 and routes the request to the correct process device according to destination information contained in the request.

5           The request is received by the destination process device 32 which responsively provides process control information back to client node 38 through communication link 40, internet 42, and node link 44. This process control information may be in accordance with Hypertext Transfer Protocol or any other suitable  
10           protocol. Hypertext Transfer Protocol has been used by the World-Wide Web global information initiative since 1990. A specification reflecting common usage of this protocol may be obtained from the Network Working Group  
15           as RFC: 1945.

          The data in accordance with Hypertext Transfer Protocol may include, for example, Hypertext Markup Language commands, Java applets, messages, or Active X data. Those skilled in the art will appreciate from  
20           FIG. 1 and this related discussion, that process devices 32 may act as web servers to client node 38. Further, client node 38 may access process devices 32 through industry-standard web browser software such as Internet Explorer which is available from Microsoft, Inc.

25           FIG. 2 is a system block diagram of process device 48 in accordance with an embodiment of the invention. Process device 48 can be a process variable transmitter or a process actuator, depending on the type of transducer connected to process device 48. Process  
30           variable transmitters are used to monitor process variables associated with fluids such as slurries, liquids, vapors and gasses in chemical, pulp, petroleum, gas, pharmaceutical, food and other fluid processing plants. Process variables include pressure,

-9-

temperature, flow, level, pH, conductivity, turbidity, density, concentration, chemical composition and other fluid properties. Process actuators include control valves, pumps, heaters, agitators, coolers, vents and other fluid controlling devices. Process device 48 includes regulator circuit 68, communication circuitry 67 including loop interface circuit 70, processor circuit 66, and memory 62, and transducer circuit 63. Transducer circuit 63 couples to a transducer 65 which can be either part of the process device 48, or external and connected by a short cable. Fluid transducer 65 transduces a property of a fluid as shown. Transducer 65 can be a sensor or, alternatively an actuator. A circuit, such as loop interface circuit 70, may be any electrical configuration (hardware, software or combination of the two) which is arranged to produce a given result.

Regulator circuit 68 may be any circuitry which conveys power to the various components of process device 48 with power received from process control loop 72. Regulator circuit 68 is adapted to couple to process control loop 72 to power process device 48 with power received from process control loop 72. In fact, regulator circuit 68 may even wholly power all electrical components of process device 48. As such, regulator circuit 68 is coupled to loop interface circuit 70, processor circuit 66, and memory 62 to provide power to those respective circuits.

Loop interface circuit 70 may be any circuit which is adapted for digital communication on a process control loop. Through loop interface circuit 70, process device 48 is adapted to couple to process control loop 72 to send and receive loop signals to and from process control loop 72. For example, if process

-10-

device 48 is to operate in accordance with one of the Fieldbus protocols, loop interface circuit 70 is adapted to send and receive Fieldbus data packets on process control loop 72.

5           Memory 62 may be any arrangement which has more than one state, and may be either permanently or selectively maintained in either state such as electrical, magnetic, etc. Memory 62 is operably coupled to processor circuitry 66. Memory 62 may store  
10 process information, communication information, device status information or a sequence of program steps to be performed by processor circuit 66. Further, memory 62 may contain portions which provide random access, or read-only access. Additionally, memory 62 may be  
15 electrically erasable, such as an electrically erasable programmable read-only memory. Memory 62 stores data representative of an internet address for the process device 48.

          Process device 48 is adapted to transduce a  
20 fluid property and communicate process control information related to the fluid property through a fluid processing environment (FIG. 1) to a remote location. Transducer circuit 63 is adapted to couple to fluid transducer 65 and couple a signal representing the  
25 transduced fluid property to or from processor circuit 66 which passes it on to or from communication circuitry 67. Communication circuitry 67 is adapted to couple to an energy limited communication bus 72 passing through the fluid handling environment. The communication  
30 circuitry communicates process control information related to the transduced fluid property over the communication bus. Memory 62 coupled to the communication circuitry is adapted to store data representing an address identifying the process device.

-11-

The address data stored represents an internet address and the communication circuitry communicates process control information together with data representative of the internet address in an energy limited form to the energy limited communication bus. The data stored in memory 62 which is representative of the internet address can be stored as the internet address itself, as data pointing to the process device's internet address stored in another device, or as data from which its address can be computed, or other convenient way of storing a representation of the address. This unique arrangement allows process device 48 to safely communicate over bus 72 in an energy limited fashion, including data which represents the internet address of the device 48. When the bus passes through to an unprotected area, the address is then directly available outside the fluid handling area for communication with an internet which does not have the energy limiting features.

Processor circuit 66 may be embodied in discrete circuitry, a microprocessor, a programmable logic array or any other suitable device. Processor circuit 66 is operably coupled to loop interface circuit 70 and memory 62. Processor circuit 66 may be adapted to receive a sensor output from transducer circuit 63 which is indicative of a process variable. Processor circuit 66 is adapted to send data to and receive data from loop interface circuit 70 which data is suitable for internet transmission.

FIG. 3 is a cross-section view of process device 49 in accordance with an embodiment of the invention. Process device 49 is one type of process device 32 (shown in FIG. 1). Process device 49 may be constructed to be suitable for hazardous environments.

-12-

As such, process device may be intrinsically safe in accordance with the intrinsic safety standard specified above, or explosion-proof, in accordance with APPROVAL STANDARD FOR EXPLOSION-PROOF ELECTRICAL EQUIPMENT  
5 GENERAL REQUIREMENTS, Class Number 3615, as promulgated by Factory Mutual Research March 1989. Thus, such a process device may be suitable for operation in hazardous environments.

Process device 49 includes housing 50 which,  
10 in cooperation with covers 52 encloses transmitter electronics 56. Process device 49 also includes sensor unit 64 which is adapted to couple to a process and provide an output which is related to a process variable. In some embodiments, sensor unit 64 may be  
15 disposed outside of process device 49. Sensor unit 64 may be any system which couples to a physical process and provides an electrical output that is related to a process variable. Sensor unit 64 may include a process sensor, such as a pressure sensor, and sensor circuitry  
20 such as circuitry 61 which may provide such features as signal linearization or the like. Sensor unit 64 is coupled to processor 66 of transmitter electronics 56.

In one embodiment of the invention, at least a portion of data transferred between processor circuit  
25 66 and loop interface circuit 70 is in accordance with the Hypertext Transfer Protocol.

In a another embodiment of the invention, memory 62 stores internet address data which uniquely identifies process device 49 on an internet. The  
30 address data may comprise at least four groups of data where each group has at least eight bits. Such an address may be expressed with each group of bits corresponding to its decimal equivalent. For example, an internet address may be 201.138.92.5 which may

-13-

correspond to a computer named "Rosemount.com". It should be noted however, that the internet address may include additional address information such as a subnet mask address or the like.

5           In this embodiment, process device 49 is particularly useful in situations where process control loop 72 has been adapted for internet addressing. Thus, instead of having process control loop source and destination addresses, process control loop packets  
10 would have source and destination internet addresses. In such a case, processor circuit 66 cooperates with loop interface circuit 70 to selectively interact with process control loop data packets which have an internet address matching that stored in memory 62. A packet is  
15 a group of digital information such as a series of digital bits.

          In another embodiment of the invention, memory 62 stores data in accordance with Hypertext Markup Language. Memory 62 is coupled to processor circuit 66  
20 such that processor circuit 66 selectively provides the Hypertext Markup Language from memory 62 to loop interface circuit 70.

          In this embodiment, process control device 49 is useful for sending and receiving Hypertext Markup  
25 Language data to and from process control loop 72.

          In yet another embodiment of the invention, processor circuit 66 is adapted to format the sensor output received from sensor unit 64 in accordance with an internet protocol. The internet protocol may be any  
30 appropriate internet protocol such as Internet Protocol as specified in RFC: 791, promulgated by the Internet Engineering Task Force September, 1981. Processor circuit 66 provides the internet-formatted sensor output to loop interface circuit 70 which then further formats

-14-

the internet-formatted sensor output for transmission upon process control loop 72.

For example, the sensor output may be a byte of digital information which is indicative of the process variable. Processor circuit 66 may then encapsulate the byte with additional digital information indicative of an internet address to which the sensor output byte will travel. The combination of internet address and data byte may be considered as an internet data packet which is provided by processor circuit 66 to loop interface circuit 70. Loop interface circuit 70 receives the data packet and formats the data packet for transmission upon process control loop 72, which may be for example a Fieldbus process control loop. As such, in this embodiment, loop interface circuit 70 adds additional data to the internet data packet to route the internet data packet on process control loop 72.

FIG. 4 is a cross-section view of process device 74 in accordance with another embodiment of the invention. Process device 74 is identical to process device 49 (shown in FIG. 3) with the exception of monitor circuitry 76, and similar components are numbered similarly. Monitor circuitry 76 may be any circuitry which senses or determines the occurrence of an event and provides a signal related to the occurrence. Monitor circuitry 76 is operably coupled to sensor system 64, and processor circuit 66. Further, monitor circuitry 76 may also be coupled to regulator circuit 68 to receive power from process control loop 72 through regulator circuit 68. Monitor circuitry 76 monitors the output from sensor system 64 to determine the occurrence of an event such as a sensor failure, alarm condition or the like.



-15-

In response to the occurrence of the event, monitor circuitry 76 causes processor circuit 66 to generate an event data packet in accordance with an internet protocol for transmission on process control  
5 loop 72. The event data packet may be any body of digital information which is related to the event. The event data packet may be indicative of the event itself, the sensor output, or both. The event data packet may be in accordance with Hypertext Transfer Protocol.  
10 Additionally, the event data packet may be selected to cause a destination device such as client node 38 (shown in FIG. 1) to execute a query upon receiving the event data packet. The event data packet may also be selected to cause another process device on the process control  
15 loop, or across an internet, to perform an action, such as closing a valve. Further, process circuitry 66 may generate additional packets which report actions taken by processor 66 in response to the event, and such report packets could be addressed through an internet to  
20 an alphanumeric pager, or the like.

In one example, monitor circuitry 76 may determine that a sensor has failed and provide a signal related to such occurrence to processor 66. Processor 66 may then send commands to other process devices to  
25 enter a fail-safe mode. Processor 66 could then send additional information to a pager, alerting a supervisor to the condition.

FIG. 5 is a cross-section view of process device 80 in accordance with another embodiment of the  
30 invention. Process device 80 includes some components which are similar, or identical to components in the above described embodiments, and such components are numbered similarly. Process device 80 includes regulator 68, loop interface circuit 70, processor

-16-

circuit 66, memory 62, internet protocol circuit 84, and transmission circuit 82.

5        Loop interface circuit 70 is coupled to internet protocol circuit 84 which is further coupled to transmission circuit 82. Transmission circuit 82 is coupled to processor circuit 66.

10        Processor circuit 66 is adapted to receive an output signal from sensor system 64, which is indicative of a process variable. Processor circuit 66 provides output data which, for example, may be indicative of the sensor output signal. Additionally, processor circuit 66 may be adapted, to receive input data from transmission circuit 82.

15        Transmission circuit 82 is coupled to processor circuit 66 to receive the output data from processor circuit 66. Transmission circuit 82 may also provide the input data to processor circuit 66. Transmission circuit 82 transforms the output data received from processor circuit 66 into output segments to be provided to internet protocol circuit 84. Conversely, transmission circuit 82 also assembles input segments received from internet protocol circuit 84 into input data to be provided to processor circuitry 66. A segment is any data passed between transmission circuit 25 82 and internet circuit 84.

30        Transmission circuit 82 may operate in accordance with various transmission control protocols such as Transmission Control Protocol (TCP) as defined in RFC 793, promulgated by the Internet Engineering Task Force, or User Datagram Protocol (UDP) as defined in RFC 768, promulgated by the Internet Engineering Task Force. Further, the data exchanged between transmission circuit 82 and processor circuit 66 may be in any of a variety of suitable protocols such as Hypertext Transfer

-17-

Protocol, File Transfer Protocol (FTP), Simple Message Transfer Protocol (SMTP), Telnet Protocol, Simple File Transfer protocol (SFTP), or Trivial File Transfer Protocol (TFTP).

5           Internet protocol circuit 84 is operably coupled to transmission circuit 82 and is adapted to provide an output packet for each output segment received from transmission circuit 82. An output packet generally comprises an output segment provided by  
10       transmission circuit 82, data indicative of the transmission protocol used by transmission circuit 82, and an internet address to which the packet will travel. Thus, if transmission circuit 82 uses Transmission Control Protocol (TCP) to create the output segments,  
15       the output packets would so indicate.

          Internet protocol circuit 84 may be adapted to receive input packets from loop interface circuitry 70 and selectively provide input segments to transmission circuit 82. Such selection, is based upon checking data  
20       in the input packets to determine if the input packets have been formatted in accordance with the same transmission protocol as that provided by transmission circuit 82. If the input packets have been so formatted, then input segments, corresponding to the  
25       input packets are provided from internet protocol circuit 84 to transmission circuit 82.

          Loop interface circuitry 70 is adapted to generate process control loop signals in response to and based upon reception of output packets from internet  
30       protocol circuit 84. Further, loop interface circuitry 70 may also be adapted to selectively provide input packets to internet protocol circuit 84 based upon received process control loop signals.

-18-

Although the present invention as been described with respect to process devices providing sensor information on a process control loop, those skilled in the art will appreciate that the present invention is equally applicable to process devices which receive information from the process control loop and responsively cause a physical change in a process.

For example, in FIG. 5, replacing sensor system 64 with an actuator system such as a valve would allow processor circuit 66 to provide digital output signals to the actuator system to thereby modify a process variable. This substitution would essentially convert any of the process devices described above into process devices which physically affect a process. Further, it is entirely within the scope of the present invention to provide a process device which not only senses a process variable, but also affects a process variable. Further, although the embodiments shown in FIGS. 2 through 5 are described with respect to individual circuits, such notation is merely provided for clarity. Thus, the present invention may be practiced by combining various modules on an application specific integrated circuit, or by implementing the various circuits in a microprocessor with software.

FIG. 6 is a block diagram of a sequence of program steps which could be implemented on processor 66 to practice the invention. The sequence shown in FIG. 6 depicts how a process device in accordance with an embodiment of the invention acts as an internet information server.

Server operation begins when the processor receives a request for information as indicated at block 90. Such a request may come from a device such as client node 38 (shown in FIG. 1) or from an internal

-19-

device such as a timer. Those skilled in the art will appreciate that if a timer is used, then the process device essentially pushes process information to a destination device.

5           At block 92, the processor determines what information is requested and accesses the requested information. For example, the request may be directed to obtaining process control information, process device information, or both. Block 92 is completed when the  
10 processor stores the requested information in memory, such as memory 62 (shown in FIGS. 2-5).

          At block 94, the processor formats the requested information for internet transmission. When a relatively large amount of information is to be  
15 transmitted, information must be broken up into discrete segments. In this case formatting would likely entail breaking the requested data into segments such as those in accordance with Transmission Control Protocol. However, if the amount of requested information is  
20 sufficiently small, other suitable protocols may be used such as, User Datagram Protocol. Block 94 is concluded when the processor stores the formatted information in memory along with an indication of which particular type of formatting protocol was used.

25           After block 94, the processor executes the program step shown at block 96. Specifically, additional information such as an internet address of the destination device (generally the requesting device), and an internet address of the process device  
30 are stored in memory along with the formatted requested information.

          At step 98, additional information is accessed by the processor to determine a process control loop address of a communication device which will forward the

-20-

information on to the internet. Such information is stored in memory along with a process control loop address of the process device (source address).

At block 100, the processor provides the  
5 stored memory contents (formatted requested information; format type; internet addresses; and process control loop addresses) to a loop interface module which interacts with hardware to introduce signals onto the process control loop which correspond to the memory  
10 contents.

FIG. 7 is a block diagram of a data structure  
102 in accordance with an embodiment of the invention. Data structure 102 includes data block 104, transmission control protocol header 106, internet protocol header  
15 108, and process control loop header 110. The data structure shown in FIG. 7 may take various specific forms such as, when data 104 is a combination of process information and Hypertext Markup Language data; transmission control protocol header 106 is in  
20 accordance with User Datagram Protocol; IP header 108 is in accordance with Internet Protocol; and loop header 110 is in accordance with the Fieldbus protocol. Further, data trailers may also be used, such as an end delimiter for the process control loop. Those skilled  
25 in the art will appreciate that a variety of combinations are possible with the invention. The data structure shown in FIG. 7 is assembled in a process device prior to transmission on a process control loop, and is also received from a process control loop in  
30 order to have data 104 extracted. As such, data structure 102 may be found in memory in a given process device, in transit across a process control loop, or in a memory of a process communication device.

-21-

FIG. 8 a system block diagram of process communication device 34 in accordance with an embodiment of the invention. Process communication device 34 includes loop communication circuitry 116, internet communications circuitry 120, memory 122, and power supply circuit 124. Loop communication circuitry 116 is adapted to couple to process control loop 126 to send and receive process control loop signals to and from process control loop 126. It should be noted that process control loop 126 may be any appropriate process control loop which provides digital communication between devices on the process control loop. Loop communication circuitry 116 is coupled to memory 122 which contains data indicative of a loop address of communication device 34 on process control loop 126. Thus, loop communication circuitry 116 is able to determine when process control loop data is addressed to process communication device 34 by comparing the loop address contained in memory 122 with destination device information received from the process control loop 126. Loop communication circuitry 116 is coupled to internet communication circuitry 120.

Internet communication circuitry 120 is adapted to couple to an internet through communication link 40. Internet communication circuitry 120 is coupled to memory 122, which contains data indicative of an internet address of communication device 34.

When process communication device 34 is operating to transmit data from process control loop 126 to an internet, loop communication circuitry 116 receives a loop packet from process control loop 126 which contains the loop address of process communication device 34 as stored in memory 122. Loop communication circuitry 116 is adapted to extract an internet packet

-22-

from the loop packet which is received from process control loop 126. An internet packet is any body of data which includes internet routing data such as an IP address. Loop communication circuitry 116 provides the  
5 extracted internet packet to internet communication circuitry 120 which formats the packet for transmission through link 40. Internet communication circuitry 120 then transmits the formatted internet packet through link 40 into the internet to which link 40 is connected.

10 When process communication device 34 works in the opposite direction, an internet packet which has been formatted for transmission through link 40 arrives at internet communication circuitry 120. Internet communication circuitry 120 extracts the internet packet  
15 from the data received from link 40. Internet communication circuitry 120 then determines if the destination for the received internet packet is a process control device which resides upon process control loop 126. If so, internet communication  
20 circuitry 120 passes the internet packet to loop communication circuitry 116 which encapsulates the internet packet with process control loop routing information and introduces the so formatted packet onto process control loop 126 for transmission to the  
25 destination process control device.

As can be seen in FIG. 8, communication device 34 also includes power supply 124 which is adapted to couple to process control loop 126 to inject power into process control loop 126. Power supply 124 may be  
30 coupled to a power source 128 which is external to process control loop 126.

In some embodiments of the invention, the format of loop packets may be the same as the format of information received from link 40. For example, when



-23-

link 40 is in accordance with an Ethernet data network, and process control loop 126 is in accordance with high-speed Fieldbus (H2), the packets may be so similar, that little if any reformatting is required. In this embodiment, process communication device 34 still adapts the data by changing signal levels. Thus, although an Ethernet network may not be intrinsically safe, process communication device 34 may affect the signal levels to such an extent that intrinsic safety compliance of process control loop 126 is maintained.

As can be appreciated, the present invention provides a variety of process devices, and a process communication device which allow for individual process devices to serve as internet communication devices. Thus, a transmitter in accordance with the present invention may perform the function of a web server allowing a variety of users employing various platforms to access transmitter data and receive process information. Further, software updates can now be provided to the process devices through the public Internet, thus reducing administrative effort. Additionally, users of the present invention by interacting through the internet with the process devices can effect process changes. As can also be appreciated, because the present invention employs traditional process control loops, the present invention may be practiced with intrinsically safe process control devices without endangering intrinsic safety compliance. The various embodiments set forth herein may be implemented alone or in combination(s) as desired or as appropriate.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes

-24-

may be made in form and detail without departing from the spirit and scope of the invention.

-25-

WHAT IS CLAIMED IS:

1. A process device adapted to couple to a fluid process control loop, the device comprising:
  - loop interface circuitry adapted to couple to the process control loop to send and receive loop signals on the process control loop;
  - processor circuitry coupled to the loop interface circuitry adapted to provide internet-compatible data to the loop interface circuitry for transmission upon the process control loop; and
  - a memory coupled to the processor and adapted to store data related to internet communication.
2. A process device adapted to couple to a fluid process control loop, the process device comprising:
  - loop interface circuitry adapted to couple to the process control loop to send and receive loop signals to and from the process control loop;
  - processor circuitry operably coupled to the loop interface circuitry and adapted to receive a sensor output and provide data indicative of the sensor output to the loop interface circuitry for transmission upon the process control loop; and
  - a memory operably coupled to the processor circuitry, the memory adapted to contain data in accordance with Hypertext Markup Language.
3. A process device adapted to couple to a fluid process control loop, the process device comprising:

-26-

means for providing power to the process device with power received from the process control loop;

loop communication means for communicating on the process control loop;

processor means coupled to the loop communication means, for providing a sensor output to the loop communication means; and

memory means operably coupled to the processor means for providing data to the processor means in accordance with Hypertext Markup Language.

4. A process device adapted to couple to a fluid process control loop, the process device comprising:

loop interface circuitry adapted to couple to the process control loop to send and receive loop signals to and from the process control loop;

processor circuitry operably coupled to the loop interface circuitry and adapted to receive a sensor output, the processor circuitry adapted to provide data to and receive data from the loop interface circuitry;

a memory operably coupled to the processor and adapted to store data; and

wherein at least a portion of the data communicated between the processor and loop interface circuitry is in accordance with Hypertext Transfer Protocol.

5. A process device adapted to couple to a fluid process control loop, the process device comprising:

-27-

a regulator circuit adapted to couple to the process control loop and power the process device with power received from the process control loop;

loop interface circuitry adapted to couple to the process control loop to send and receive loop signals to and from the process control loop;

processor circuitry operably coupled to the loop interface circuitry, the processor adapted to receive a sensor output;

a memory operably coupled to the processor, the memory adapted to contain an internet address of the process device; and

wherein the loop interface circuitry is configured to receive data packets from the process control loop which contain the internet address and to transmit data packets on the process control loop which include the internet address.

6. The process device of claim 5 wherein the internet address is an Internet Protocol address as defined by RFC 791, promulgated by the Internet Engineering Task Force September, 1981.

7. The process device of claim 5 wherein the internet address comprises at least four groups of data each group comprising at least eight bits.

8. A process device adapted to couple to a fluid process control loop, the process device comprising:

means for providing power to the process device with power received from the process control loop;

means for storing an internet address; and

-28-

means for sending and receiving data containing the internet address to and from the process control.

9. A process device adapted to couple to a fluid process control loop, the process device comprising:

loop interface circuitry adapted to couple to the process control loop to send and receive loop signals to and from the process control loop;

processor circuitry operably coupled to the loop interface circuitry, the processor circuitry adapted to receive a sensor output and format the sensor output in accordance with an internet protocol and provide the formatted sensor output to the loop interface circuitry for transmission on the process control loop.

10. The process device of claim 9 wherein the internet protocol is Internet Protocol as defined by RFC 791, promulgated by the Internet Engineering Task Force, September, 1981.

11. A process device adapted to couple to a fluid process control loop, the process device comprising:

a regulator circuit adapted to couple to the process control loop and power the process device with power received from the process control loop;

loop interface circuitry adapted to couple to the process control loop to generate process control loop signals in accordance with a process control loop protocol in response to reception of output packets, and selectively provide

-29-

input packets based upon received process control loop signals;  
internet protocol circuitry operably coupled to the loop interface circuitry and adapted to provide the output packets to the loop interface circuitry in accordance with an internet protocol and based upon output segments received by the internet protocol circuitry, each output packet comprising an output segment, a source internet address, a destination internet address, and data indicative of a transport type, the internet protocol circuitry further adapted to receive the input packets from the loop interface circuitry;  
transmission circuitry operably coupled to the internet protocol circuitry and adapted to transform output data received by the transmission circuitry into the output segments, and assemble input segments received from the internet protocol circuitry into input data; and  
processor circuitry adapted to receive a sensor output, and provide the output data to the transmission circuitry and receive input data from the transmission circuitry.

12. The process device of claim 11 wherein the transmission circuitry transforms data in accordance with Transmission Control Protocol as defined by RFC 793, promulgated by the Internet Engineering Task Force.

-30-

13. The process device of claim 11 wherein the transmission circuitry transforms data in accordance with User Datagram Protocol as defined by RFC 768, promulgated by the Internet Engineering Task Force.

14. A program on a computer readable medium comprising:

- a data access routine for obtaining fluid process data;
- a formatting routine for formatting the fluid process data in accordance with a transmission protocol;
- an addressing routine for adding a destination internet address to the formatted data; and
- a loop formatting routine for adding a process loop destination address to the formatted data and internet address.

15. A data structure embodied in a fluid process device, the data structure comprising:

- a data field;
- a transmission control header;
- an internet protocol header; and
- a process control loop header.

16. A process device adapted to couple to a fluid process control loop, the process device comprising:

- a regulator circuit adapted to couple to the process control loop and power the process device with power received from the process control loop;
- loop interface circuitry adapted to couple to the process control loop to send and receive loop signals to and from the process control loop;



-31-

processor circuitry operably coupled to the loop interface circuitry, the processor circuitry adapted to receive a sensor output; and

a memory coupled to the processor circuitry and adapted to store instructions for execution upon the processor circuitry the processor circuitry, the instructions comprising:

an internet formatting routine for formatting the sensor output in accordance with an internet protocol;

a loop formatting routine for further formatting the internet-formatted output for transmission on the process control loop;

an output routine to cause the processor to provide the formatted sensor output to the loop interface circuitry for transmission on the process control loop.

17. A process communication device adapted to couple to a fluid process control loop, the device comprising:

a memory adapted to contain data indicative of a loop address of the device, and an internet address of the device;

loop communication circuitry, coupled to the memory, and adapted to communicate on the process control loop;

internet communication circuitry coupled to the loop communication circuitry and the memory, and adapted to couple to an

-32-

internet to communicate on the internet;  
and

wherein the internet communication circuitry passes information received from the internet to the loop communication circuitry for transmission upon the process control loop, and the loop communication circuitry passes information received from the process control loop to the internet communication circuitry for transmission upon the internet.

18. A process device adapted to transduce a fluid property and communicate process control information related to the fluid property through a fluid processing environment to a remote location, the device comprising:

a transducer circuit adapted to couple between a fluid transducer and a signal representing the transduced fluid property;

communication circuitry adapted to couple to an energy limited communication bus through the fluid handling environment, the communication circuitry communicating process control information related to the transduced fluid property over the communication bus;

a memory coupled to the communication circuitry adapted to store data representing an address indentifying the process device;

wherein the address is an internet address and the communication circuitry

-33-

communicates process control information together with data representative of the internet address in an energy limited form to the energy limited communication bus.

19. The process device of claims 1, 2, 4, 9 or 18, and further comprising a regulator circuit adapted to couple to the process control loop and power the process device with power received from the process control loop.

20. The process device of claim 19 wherein the regulator wholly powers the process device with power received from the process control loop.

21. The process device of claims 1, 2, 3, 4, 5, 8, 9, 11, 16, or 17, wherein the fluid process control loop is a two-wire process control loop.

22. The process device of claims 1, 2, 4, 5, 9, 11 or 16, wherein the processor circuitry is embodied in a microprocessor.

23. The process device of claims 1, 2, 3, 4, 5, 8, 9, 11 or 16, wherein the process device is intrinsically safe.

24. The process device of claims 1, 2, 3, 4, 5, 8, 9, 11, or 16, wherein the process device is explosionproof.

25. In a process device on a fluid process control loop, a method of transmitting data on the fluid process control loop, the method comprising:

obtaining data related to a fluid process;  
formatting the data for internet transmission;  
formatting the data for transmission upon the fluid process control loop; and

-34-

introducing the formatted data onto the fluid process control loop.

26. A process device adapted to couple to a fluid process control loop, the process device comprising:
- circuitry adapted to carry out a method of transmitting data on the fluid process control loop, the method comprising:
    - obtaining data related to a fluid process;
    - formatting the data for internet transmission;
    - formatting the data for transmission upon the fluid process control loop; and
    - introducing the formatted data onto the fluid process control loop.

1/8

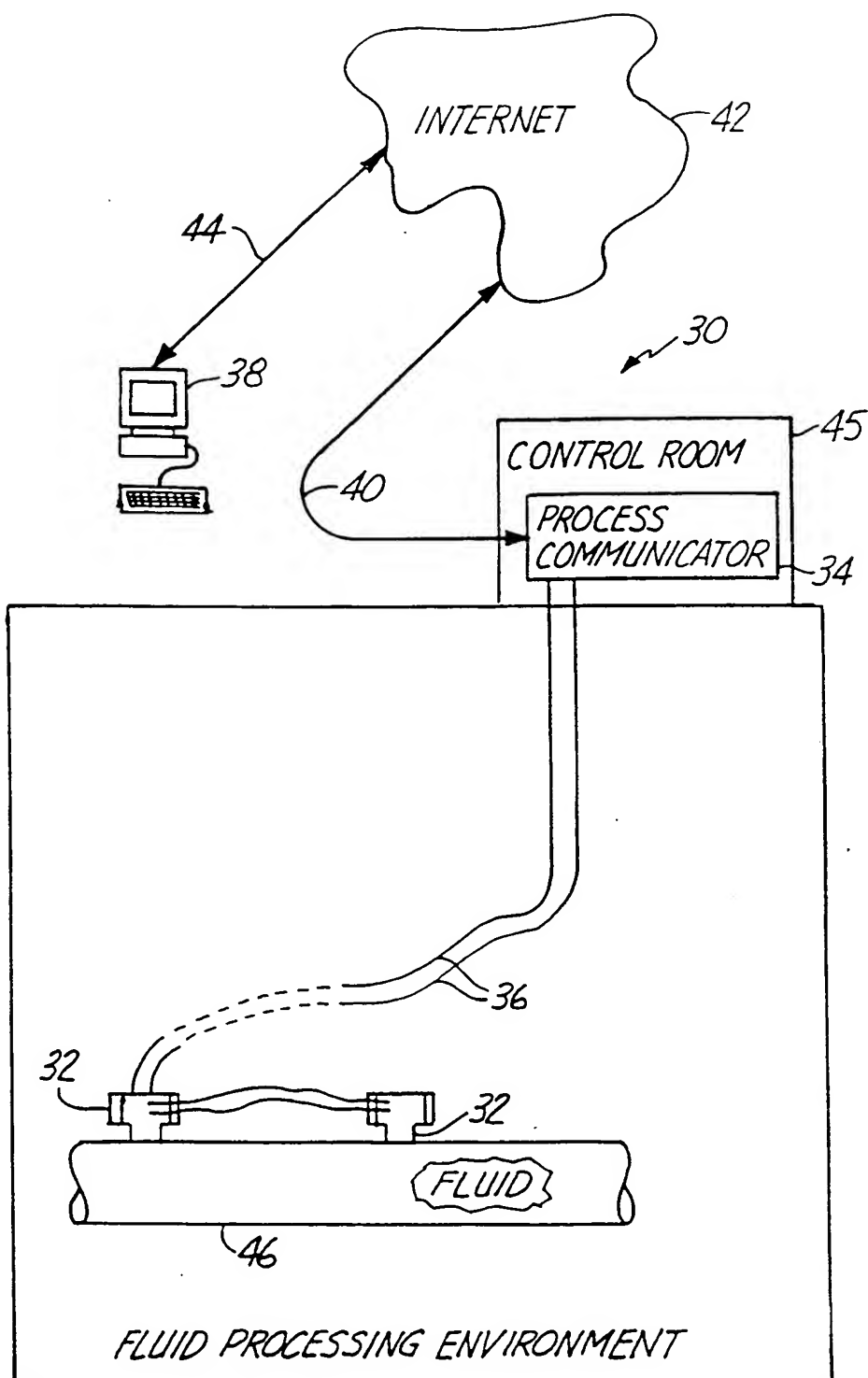


Fig. 1

2/8

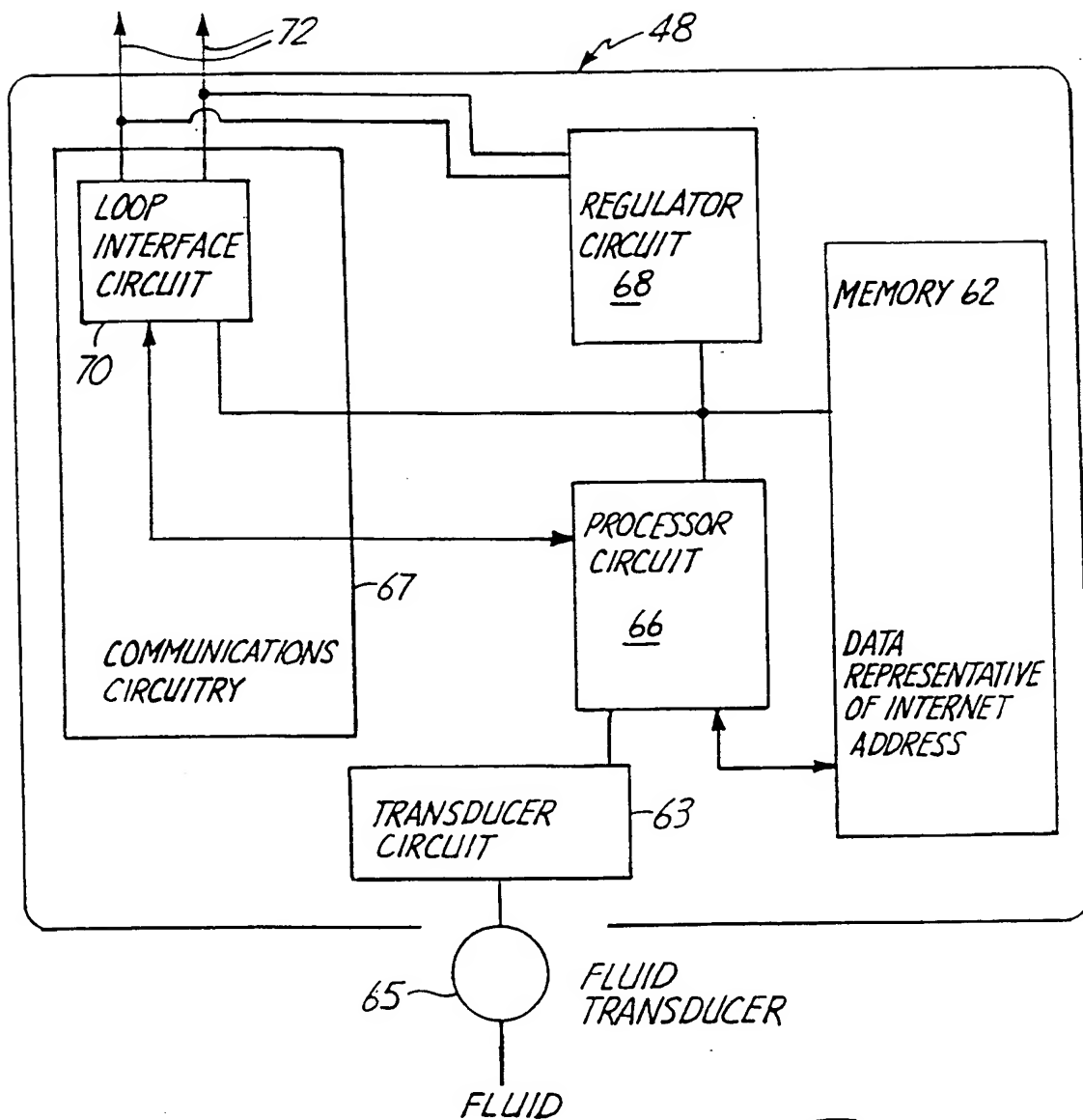


Fig. 2

3/8

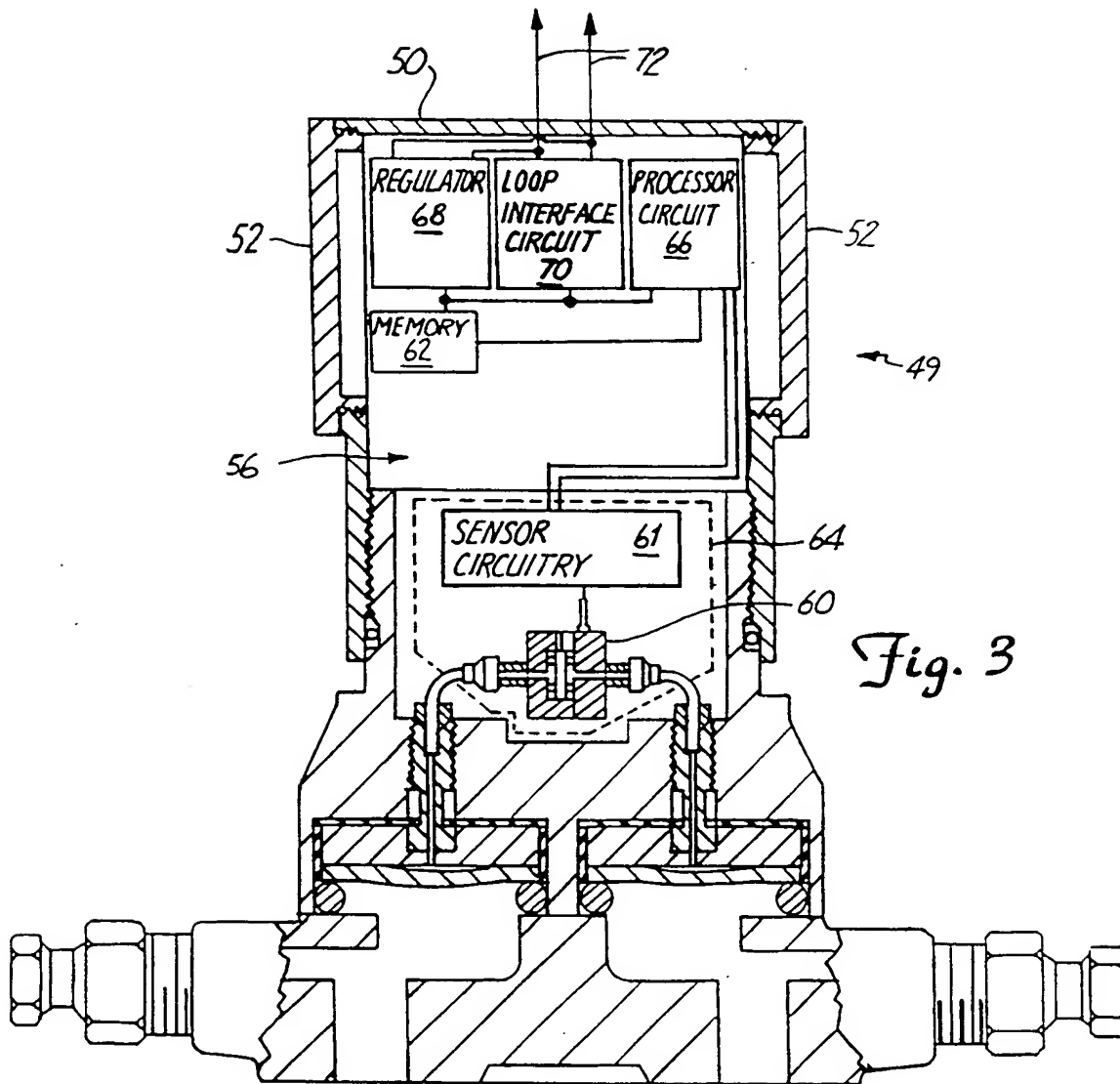


Fig. 3

4/8

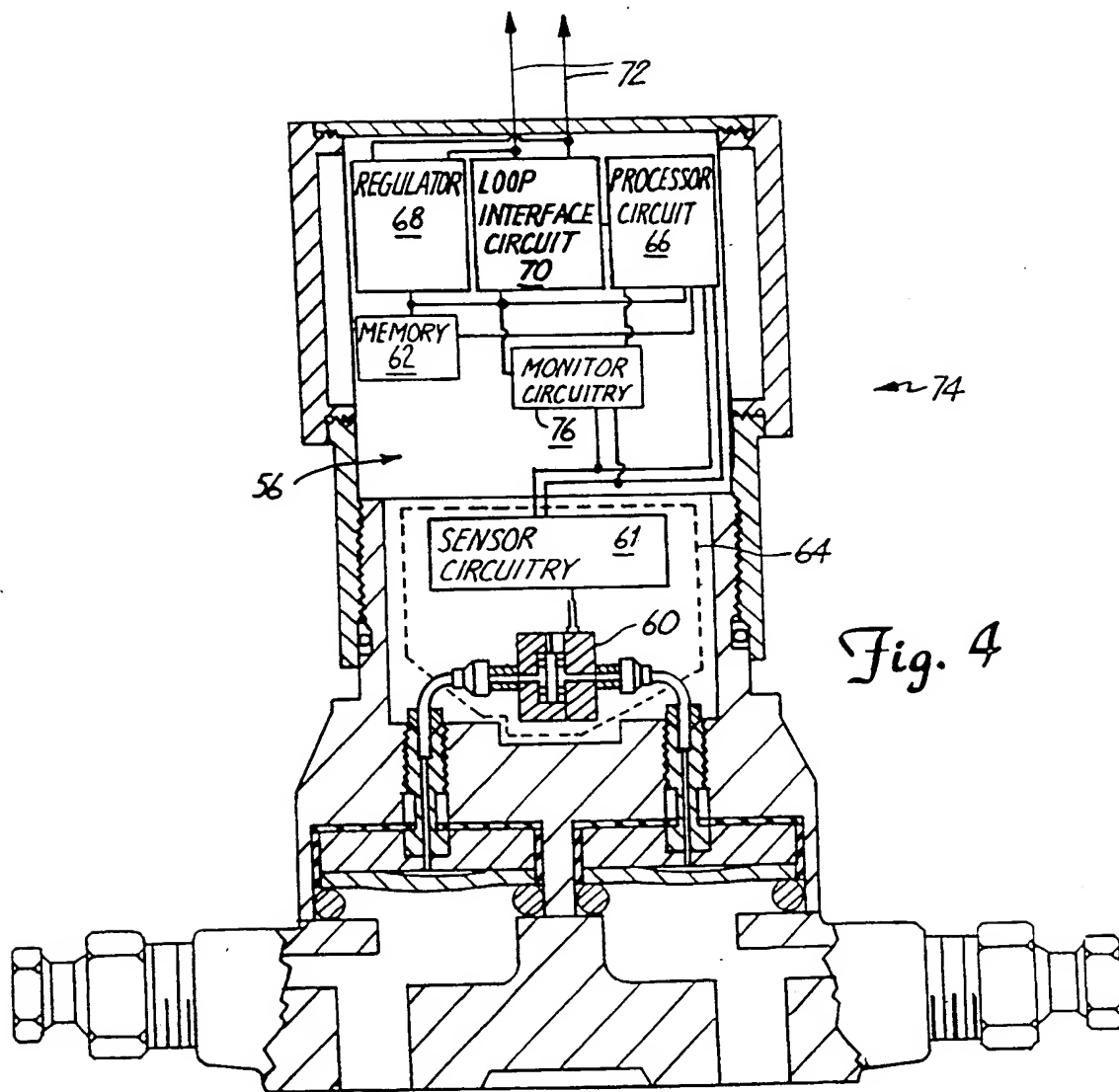


Fig. 4



5/8

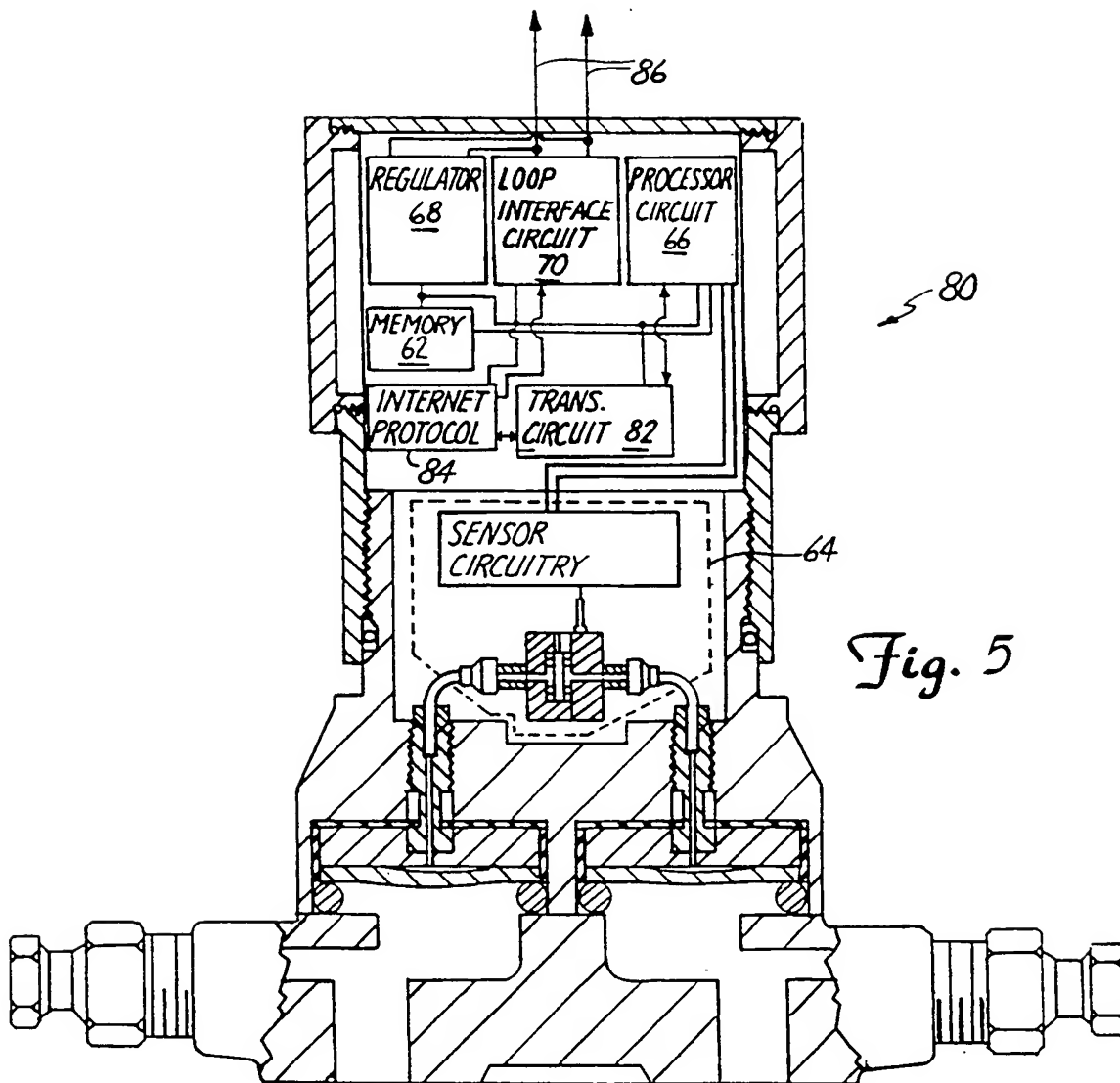


Fig. 5

6/8

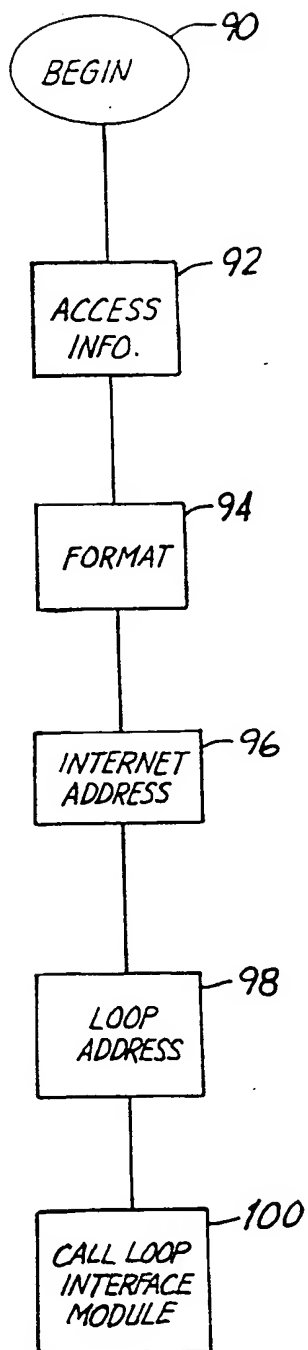
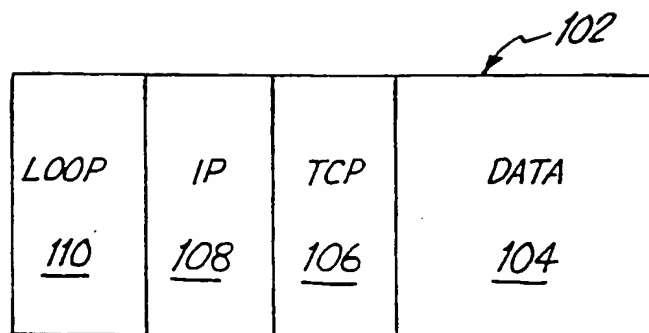


Fig. 6

7/8

*Fig. 7*

8/8

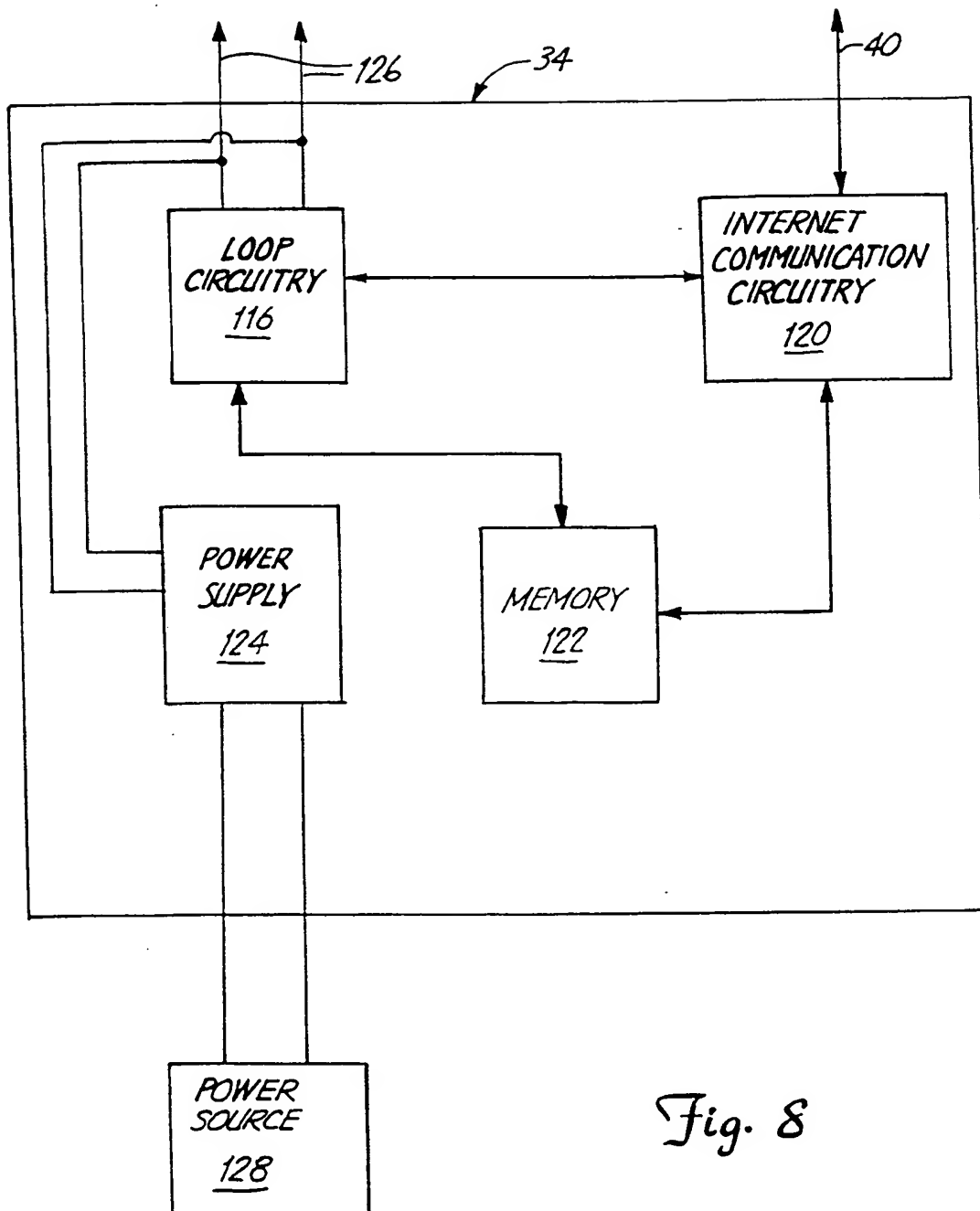


Fig. 8

## INTERNATIONAL SEARCH REPORT

Intern. Appl. No.

PCT/US 98/21339

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G05B19/418 G05B19/042

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 296 00 609 U (SIEMENS AG) 13 February 1997  see the whole document ----	1-5, 8, 9, 11, 16-18, 25, 26
A	GB 2 310 346 A (ROSEMOUNT INC) 20 August 1997 see the whole document ----	1-26
A	US 5 573 032 A (LENZ GARY A ET AL) 12 November 1996 see the whole document ----	1-26
A	WO 96 12993 A (FISHER ROSEMOUNT SYSTEMS INC) 2 May 1996 see the whole document -----	1-26



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&amp;" document member of the same patent family

Date of the actual completion of the international search

26 January 1999

Date of mailing of the international search report

02/02/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Hauser, L

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/21339

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 29600609 U	13-02-1997	WO 9726587 A EP 0875023 A	24-07-1997 04-11-1998
GB 2310346 A	20-08-1997	US 5764891 A CA 2197600 A DE 19705734 A	09-06-1998 16-08-1997 21-08-1997
US 5573032 A	12-11-1996	US 5549137 A BR 9407585 A CN 1129480 A EP 0739503 A JP 9502292 T SG 44472 A WO 9506276 A US 5558115 A	27-08-1996 07-01-1997 21-08-1996 30-10-1996 04-03-1997 19-12-1997 02-03-1995 24-09-1996
WO 9612993 A	02-05-1996	AU 3955395 A BR 9509503 A CN 1170464 A EP 0788627 A FI 971739 A JP 10508129 T NO 971867 A US 5682476 A US 5793963 A	15-05-1996 30-12-1997 14-01-1998 13-08-1997 23-04-1997 04-08-1998 09-06-1997 28-10-1997 11-08-1998